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INVESTIGATION ON A NEW MECHANICAL SUPERCHARGER ——SCROLL SUPERCHARGER

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ABSTRACT

A new mechanical supercharger—— a low compression ratio scroll compressor was introduced in this paper, including the principle, scroll geometry, suction volume, inner compression ratio, etc. Then the advantages of the scroll supercharger were pointed out compared with other superchargers. After some concrete design considerations, a prototype was made and the performance tests showed the results and prospect of scroll superchargers.

INTRODUCTION

As we have seen, an internal combustion engine converts some of the energy released during combustion process to useful work; however, there is an upper thermodynamic limit to the efficiency of convertion and a practical limit to the degree of success in approaching the thermodynamic efficiency, the power produced by an engine is approximately proportional to the quality of fuel burnt, and the latter is controlled by the air supplied to the engine. In naturally aspirated four-stroke engines the quantity of air is proportional to the volume swept by the piston (or some percentage in excess in two-stroke engine). In order to increase the air supply an external air source is required. When this is provided the engine is said to be supercharged. One of the methods is provide a separate pump to supply air to the engine. the air pump may be driven from the crankshaft or connecting rod or by a separate electric motor. This method is normally called mechanical supercharging. Another method is turbocharging.

Until now mainly turbocharging and four valves per cylinder are used to realize a high specific performance of spark ignition engines. Both technologies of power increase are characterized by just a small improvement in engine torque at low engine speeds. In contrast to this the application of a crankshaft driven positive displacement supercharger helps to reach a high rated power combined with high torque in the range of low engine speeds. The use of a supercharger that is especially effective on small displacement otto and disel engines has the additional advantage of immediate dynamic response.

From recent decades a variety of supercharger designs is known. Among them the scroll supercharger is a novel supercharger (first exhibited in 1985), and will be described and studied in this report.

PRINCIPLE AND GEOMETRY

Basic Structure

The basic structure of scroll supercharger, as shown in Figure 1, consists of fixed scroll, orbiting scroll, anti- rotation mechanism and crankshaft. The two scrolls are generally defined by involutes of circles and assembled with a 180° phase difference.

The fixed scroll is attached to the crankshaft, while the moving scroll orbits by means of the crankshaft. The anti-rotation mechanism permits the moving scroll only to orbit and prevents any rotation.

Basic Concept

The orbiting scroll separates the scroll case into an inner and an outer crescent shaped chamber. Looking at phase 1 in Fig. 2 the inner and outer chambers are open to ambient. After 90° angular motion of the crankshaft (phase 2 in Fig. 2) the inner and outer chambers have extended and filled with air. The outer chamber is closed to ambient. After another 90 angular motion of the crankshaft (phase 3) the volume of the inner chamber is still growing and the air of the outer chamber is displaced towards the hub. Turning the crankshaft further the inner chamber is closed to the ambient (phase 4). The enclosed volume is then displaced to the hub, where the airflows from the outer and inner chambers mix and leave the housing to travel to the charge air cooler or intake manifold of the engine.

Geometric Relations

Fig. 3 shows the two involutes of the basic circle. The basic geometric variables which determine scroll profiles are involute thickness, t, involute pitch, p_t, involute starting angle Φ_S, involute ending angle Φ_E and the wrap height , H. The radius of generating circle, Rg, is formulated by

$$R_g = P_t/2\pi \tag{1}$$

The suction volume in 2π angular motion of the crankshaft is as follows:

$$V_S = p_t(p_t - 4t)(\Phi_E - \frac{5\pi}{4}) \cdot H \tag{2}$$

The discharge volume of the supercharger in 2π angular motion of the crankshaft is calculated by

$$V_d = p_t(p_t - 4t)(\Phi_S + \frac{3}{4}\pi)H \tag{3}$$

Thus, the design built-in volume reduction ratio is obtained by dividing V_S by V_d

$$\varepsilon_v = V_S/V_d = (4\Phi_E - 5\pi)/(4\Phi_S + 3\pi) \tag{4}$$

And the radius of orbit , or eccentricity, is

$$R_{or} = P_t/4 - t \tag{5}$$

In the case of the scroll supercharger, due to the large number of variables, the optimization study becomes more complex similar to scroll compressor. In order to generate a scroll pumping geometry, it is required to satified Equation (1)~(5). From a design point of view, the number of unknowns are more than the governing equations. Thus, it is very important to recognize the influence of each parameter to tailor the concept according to specific needs.

STRUCTURE DESIGN

Advantages of Scroll Supercharger

Compared with other superchargers, such as zoller vane charger, Roots rotary piston charge, etc, the soft opening and closing characteristic of scroll eliminates heavy pulsations in the airflow. Because of this low pulsation level of the air flow, the intake noise emission is relatively moderate. This is an important factor in regard to the use of the supercharger in passenger cars.

The low inertia of the orbiting scroll reduces ths stress for the belt drive and makes it possible to install a clutch for optimum fuel economy in the part load operating range of the engine.

Design Considerations

Fig. 4 shows the design of the scroll supercharger, whose anti-rotation mechanism consists of two cross slider blocks. The fixed scroll and orbiting scroll must be manufactured to special sepcifications relating to part fit, dimensional and positional tolerances, surface quality, desired clearance and material treatment.

To reduce the weight of the supercharger and the inertia force of the orbiting scroll, the fixed and orbiting scrolls are of aluminium in treatment. The driveshaft is of case-hardened steel.

The compression ratio of the air within the supercharger depends on the design of the scroll.

The supercharger utilizes axially sealed chambers which are located between the orbiting spirals of the moving scroll and the fixed spirals of the fixed scroll. In order to create a seal, a tempered bronze sealing strip is used with a corrugated sealing strip spring located beneath it. The seals are located in the groove which is milled into the face surface of the charger casing spirals. No corrugated sealing strip spring is placed in the orbiting spiral groove, since the high centrifugal force would cause the spring to cut gradually into the aluminium wall of the groove in the orbiting scroll. The velocity of the orbiting scroll and its sealing strip relative to the fixd scroll is low even at high rotational speeds. This assures adequate service life.

RESULT AND TEST

Fig. 5 showed the feafures of the scroll supercharger. when the capacity of the air-flow increases, nearly the charged preasure ratio did not changed and the adiabatic efficiency degraded gradually due to mechanical and friction losses increased. The capacity of the air-flow did not changed linearly with the rotation speeds of the crankshaft.

Fig. 6 showed the test results of the scroll supercharger in the charged pressure ratio——the capacity of the air-flow diagram, which is important to the matching of the scroll supercharger with the engine.

CONCLUSION

Compared with other mechanical superchargers scroll supercharger has higher adiabatic efficiency and low noise level and will be used in small displacement engines especially installed for passenger cars in the future. Now the key problem about scroll supercharger is to reduce the cost.

REFERENCES

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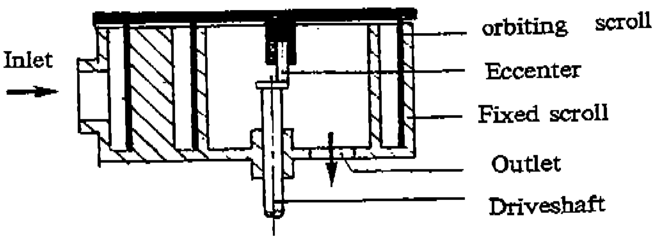

Fig. 1 Basic structure

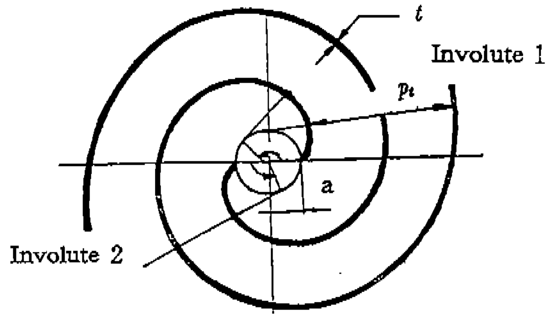

Fig. 3 Two Involutes of the Base circle

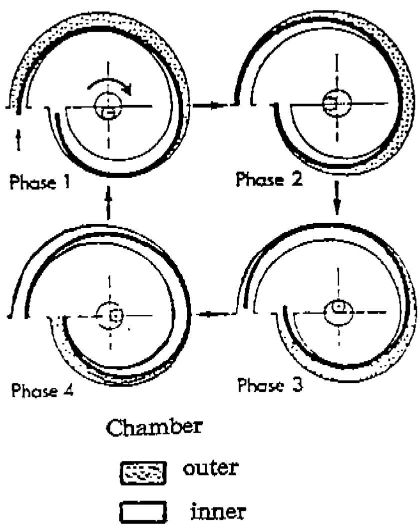

Fig. 2 The Principle

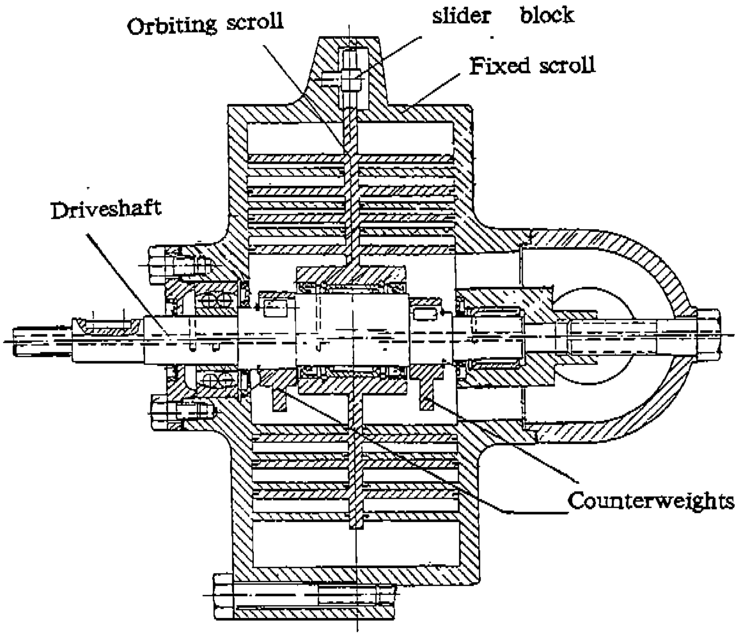

Fig. 4 Scroll Supercharger Configuration

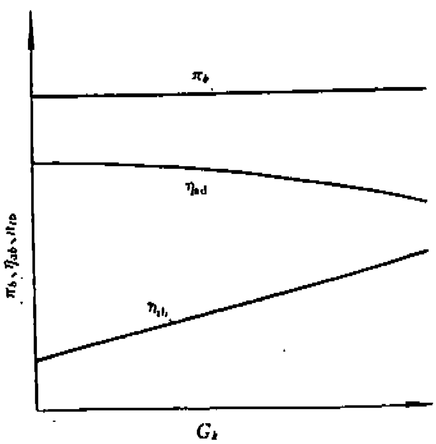

Fig. 5 Calculation Results

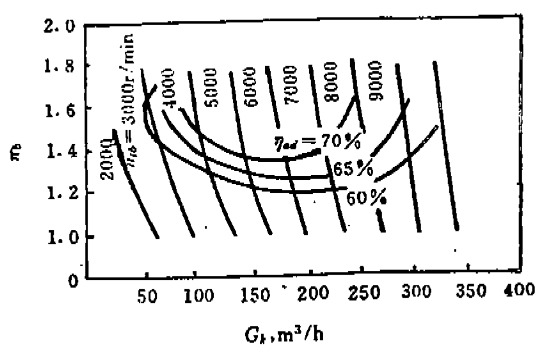

Fig. 6 π_b—Q Diagram